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Estimation of greenhouse gas (GHG) emission and energy use efficiency (EUE) analysis in rainfed canola production (case study: Golestan province, Iran)

Hossein Kazemi*, Saeid Hassanpour Bourkheili, Behnam Kamkar, Afshin Soltani, Kambiz Gharanjic, Noor Mohammad Nazari

Department of Agronomy, Faculty of Plant Production, Gorgan University of Agricultural Sciences and Natural Resources (GUASNR), PO Box 49189-43464, Gorgan, Iran

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ABSTRACT

Increasing the use of energy inputs in agricultural section has been led to numerous environmental concerns such as greenhouse gas (GHG) emissions, high consumption of non-renewable resources, loss of biodiversity and environment pollutions. The study was aimed to analyze the energy use efficiency (EUE) and estimation of GHG emissions from rainfed–based canola production systems (RCPSs) in Iran. In this study, data were collected from 35 farms in Golestan province (northeast of Iran) by a face to face questionnaire performed and statistical yearbooks of 2014. The amount of GHG emissions (per hectare) from inputs used in RCPSs was calculated using CO_2 emissions coefficient of agricultural inputs. Results showed that the EUE and net energy (NE) were as 3.44 and 35,537.81 MJ ha^{-1}, respectively. The value of these indices for the study area indicated that surveyed fields are approximately efficient in the use of energy for canola production. The highest share of energy consumption belonged to nitrogen fertilizer (42.09%) followed by diesel fuel (39.81%). In production of rainfed canola, GHG emission was estimated as 1009.91 kg CO_2 equivalent per hectare. Based on the results, nitrogen fertilizer (44.15%), diesel fuel (30.16%) and machinery (14.49%) for field operations had the highest share of GHG emission. The total consumed energy by inputs could be classified as direct energy (40.09%), and indirect energy (59.91%) or renewable energy (2.02%) and nonrenewable energy (97.98%). These results demonstrate that the share of renewable energies in canola production is very low in the studied region and agriculture in Iran is very much dependent on non-renewable energies. In this study, the energy use status in RCPSs has analyzed and the main involved causes have been interpreted.

1. Introduction

Agriculture is becoming more dependent on energy use in forthcoming days, so as to produce sufficient nutritional material for the ever-increasing population of the world. Energy sources are limited and furthermore, the effects of excessive use of energy on the environment are drastic [1]. Effective energy use in agriculture section is one of the conditions for sustainable agricultural production, since it helps to save financial resources, conserve fossil fuels and reduce environmental pollutions [2]. Thus, identifying agricultural practices which maximize crop productivity, energy use efficiency (EUE) and minimize greenhouse gas (GHG) emissions is essential [3].

Agriculture uses energy directly as diesel fuel or electricity to operate machinery and equipment on the farm and indirectly to produce chemical fertilizers, machinery and biocides that are produced off the farm [4]. Field operations like seed-bed preparation, sowing, harvesting, transport, pumping water, grain drying and also production of chemicals require energy [5]. Increasing the use of energy inputs in agriculture had led to numerous environmental concerns such as high consumption of non-renewable energy resources, loss of biodiversity, pollution of the aquatic environment by nitrogen and phosphorus as well as by pesticides [6]. These concerns are serious in different spatial scales from single fields to

* Corresponding author.
E-mail addresses: hkazemi@gau.ac.ir (H. Kazemi), s.hassanpour.b@gmail.com (S.H. Bourkheili), kamkar@gau.ac.ir (B. Kamkar), afshin.soltani@gmail.com (A. Soltani), K.gharanjic@yahoo.com (K. Gharanjic), Moahammad_tcman@yahoo.com (N.M. Nazari).

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biosphere. Integrated farming techniques improved energy efficiency by reducing energy inputs without affecting energy outputs [7]. The efficient use of energy in agriculture with low-input energy, compared to the output of agricultural production, would minimize environmental problems such as GHG emissions and decrease reliance on fossil fuels, as well as improve sustainable agriculture as an economical production system [2].

The inevitable outcome of this vast energy consumption is the emission of CO_2 and other GHGs such as N_2O and CH_4 into the atmosphere [8]. Global warming results from GHG emissions and agricultural activities contribute to approximately 13.5% of the total global anthropogenic GHG emissions [9].

Nitrous oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2) are three GHGs of major concern that are emitted from agricultural soils, animal wastes, livestock enteric fermentation [10], the manufacture and transport of fertilizers and pesticides, and also field operations [11]. According to Synder et al. [12] emissions of N_2O from the earth's surface have increased by about 40–50% over pre-industrial levels as a result of human activity. Saljnikov et al. [13], reported that about half of the global CO_2 emissions from the soil come from decomposition of the annual plant litter including agricultural crops. Also, atmospheric concentrations of NO_2 are reported to have risen from about 270 parts per billion (ppb) during the pre-industrial era to 319 ppb in 2005. Fossil fuel combustion is considered responsible for more than 75% of human-caused CO_2 emissions [12].

Several studies have evaluated the energy balance in different field crops production in Iran and other countries, but very few studies have combined the energy analysis and GHG emissions for canola production. In India, a study was conducted to assess the EUE and GHG emissions of different tillage practices in pigeonpea–castor systems under semi-arid rainfed regions. Results showed that the fuel consumption in zero tillage was 58 and 81% lower than conventional tillage in pigeonpea and castor, respectively [14]. Saljnikov et al. [13] showed that under simplified till, the soil biological parameters were more favorable than under common till and intensive till, and shallow subsoil till maintained higher levels of soil nutrients, and reduced CO_2 emission compared with the deep subsoil till.

Biswas et al. [15] compared the life cycle global warming potential of production of wheat, meat and wool in Australia. Results showed that the life cycle GHG emissions of 1 kg of wool was significantly higher than that of wheat and sheep meat. Also, the life cycle assessment (LCA) analysis identified that the on-farm activities contributed the most significant portion of total GHG emissions from the production of wheat, sheep meat and wool.

Zhang et al. [16] studied on GHG emissions from rice nursery in China. In this study, CH_4 and N_2O fluxes were determined from different nurseries under major rice cropping systems. Results showed that flooded nursery (FN) and moist nursery (MN) decreased total CH_4 emissions by 74.2%, 72.1% and 49.6% under the rice–upland rotation cropping system (RUR), and the double rice cropping system for the early rice (EDR) and the late rice (LDR), respectively.

Improvements in EUE are keys for sustainable energy management. To increase energy efficiency, energy input should be reduced without affecting the crop yield level or increase the production yield [17]. For example balancing N fertilization with actual crop requirements and adopting minimum tillage are the most efficient techniques to reduce energy inputs [7]. Qiao et al. [18] suggested that in rainfed agricultural systems (maize–soybean–wheat rotation) in Northeastern China, the application of manure supplemented with NPK can simultaneously achieve higher grain yield and lower global warming potential compared to mineral fertilizers alone.

Canola is one of the main field crops in Iran. It is one of the main crops grown in Golestan province, northeast of Iran, with harvesting area of 16,116 ha and average grain yield of approximately 1709 kg ha^{-1} in rainfed cropping system, in 2011. It can be mentioned that about 37% of Iran's canola is produced in Golestan province. Some case studies have investigated the energy balance in different crops production in Golestan province, but very few studies have combined the EUE and GHG emissions in this province. For example, Soltani et al. [8] investigated the GHG emissions and energy analysis for canola in six different production scenarios in Gorgan region and reported that canola production results in the emission of 1028.1 kg CO_2 equivalent ha^{-1} to the atmosphere. According to this, it is essential to have a detailed analysis to the rainfed canola production system in Iran. Therefore, the objectives of current study were to investigate the energy flow and EUE of rainfed canola production and to determine the GHG emissions from canola production under rainfed cropping system in Iran.

2. Materials and methods

2.1. Study area

The study was conducted in the Golestan province, northeast of Iran, which is located within the latitudes of 36° 44′ N and 38° 05′ N and the longitudes of 53° 51′ E and 56° 14′ E. Data were collected from canola-grown fields in Bandar-e-Torkaman, Kordkouy, Gorgan and Gonbad-e-Qabous counties. The climate of this province is under the influence of Alborz mountains, Caspian Sea, the southern wildernesses of Turkmenistan, and forests. According to De-Martonne advanced climate classification system the province contains five different climates: Mediterranean, arid-desert, semi-arid, humid and semi-humid. In this region, total annual precipitation is 250–750 mm and it increases from north to south regardless of the altitude. Most of the areas are covered by rainfed farming.

2.2. Management practices

Agricultural practices for the rainfed canola-grown fields being studied included field preparation, seeding, fertilization, plant protection and harvesting. All practices applied for canola production in Golestan province were shown in Table 1. In this province, the land is tilled once between October-November. Field preparation includes moldboard plowing and disk-harrowing. Average seeding rate is around of 6–9 kg ha^{-1}. In addition, chemical fertilizers are applied approximately three times in the October-November, December-January and March-April which are corresponding to phenological stages of canola. The main varieties involve in RCPSs of Golestan are as Hyola 400, RGS00 and Hyola 308. According to results of the surveyed fields, farm size has

Table 1
Common agricultural practices for RCPSs in Golestan province, Iran.

Practices/Operations	Detail
Planting date	7 September –11 November
Varieties	Hyola 401, RGS00 and Hyola 308
Seed rate	6-9 kg ha^{-1}
Seedbed preparation period	September -November
Cropping rotation	wheat, barley, rice and soybean
Herbicide	Gallant, Gallant Super and Topic
Harvesting time	May-June
Chemical fertilizer	
N	90-120 kg ha^{-1}
P_2O_5	50-75 kg ha^{-1}
K_2O	20-35 kg ha^{-1}